Information Flow in the White Matter During a Motor Task: A Structural Connectivity Driven Approach

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Introduction: Cognitive tasks emerge from the interaction of functionally specialized cortical regions (Verhagen et al. 2013). These interactions are supported by information flow through white matter fiber bundles connecting distant cortical regions. Estimating the information flow through white matter fiber bundles would therefore provide valuable information into the necessary cortical interactions to realize a task.

In this work, we build a Bayesian network representing cortical regions and their connections using a structural connectivity driven parcellation (Gallardo et al., 2016) derived from diffusion MRI (dMRI). We then introduce Magnetoencephalography (MEG) measurements as evidence into this network to infer the information flow between cortical regions (Deslauriers-Gauthier et al., 2016). We show, for the first time, results on the interaction between the precentral, postcentral and occipital regions during a hand-movement task.

Methods: We applied our technique to subject 109123 (Male, aged 32-35) of the Human Connectome Project (HCP). First, we performed probabilistic tractography using 4000 seeds for each vertex of a pial mesh (8k vertices) representing the subject's cortex. We then obtained a connectivity driven cortical parcellation of 110 regions by using the parceling technique described in Gallardo et al. (2016). The resulting parcellation, which follows the assumption of shared physical connections, was used to identify the number of streamlines connecting region pairs and their average length. As described in Deslauriers-Gauthier et al. (2016), the identified connections were then used to build a Bayesian network which associates a probability to all possible combinations of connections and cortical region states. Specifically, each connection and cortical region at every time point can be either active or inactive. By injecting MEG data as evidence into our Bayesian network and maximizing its entropy, we are able to obtain the posterior probability that a connection is active at any given time point. Here, the MEG data consisted of averaged evoked responses of a motor task where the subject was asked to move either his left or right hand following a visual cue.

Results: Our results are illustrated in the information flow diagrams of figures 1 and 2. Each row of the graph represents a cortical region and the circles correspond to individual time points. Information flow in connections is illustrated by lines connecting cortical regions at different time points. In both cases, green indicates a high probability that a region or connection is active whereas a white indicates a low probability.

Figure 1 illustrates information flow during the left hand movement task. The first activation at 100ms shows information transfer between the left occipital region and the left precentral gyrus and correspond to known visual evoked potential delays. The second activation which last from 200ms to 300ms presents information flow between the right occipital region and the right postcentral gyrus. This activation is consistent with motor activation contralateral to the hand movement. Furthermore, activity in the precentral gyrus within this time window is consistent with the initiation of a movement occurring at 300ms. Figure 2 illustrates information flow during the right hand movement task. The activation occurring at 100ms is similar to the results obtained with the left hand movement. However, during the 200 to 300ms window the information transfer is centralized in the left precentral gyrus and the occipital region. Again, this activation is consistent with motor activation contralateral to the hand movement.

Discussion and Conclusion: We proposed a new method that combines structural information obtained from dMRI and functional information obtained from MEG. Our preliminary results obtained on HCP data show that we are able to recover information flow in the white matter that is consistent with expected cortical activation during a hand movement task.

References

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This work has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (ERC Advanced Grant agreement No 694665 : CoBCoM - Computational Brain Connectivity Mapping).

Data were provided by the Human Connectome Project, WU-Minn Consortium (Principal Investigators: David Van Essen and Kamil Ugurbil; 1U54MH091657) funded by the 16 NIH Institutes and Centers that support the NIH Blueprint for Neuroscience Research; and by the McDonnell Center for Systems Neuroscience at Washington University.

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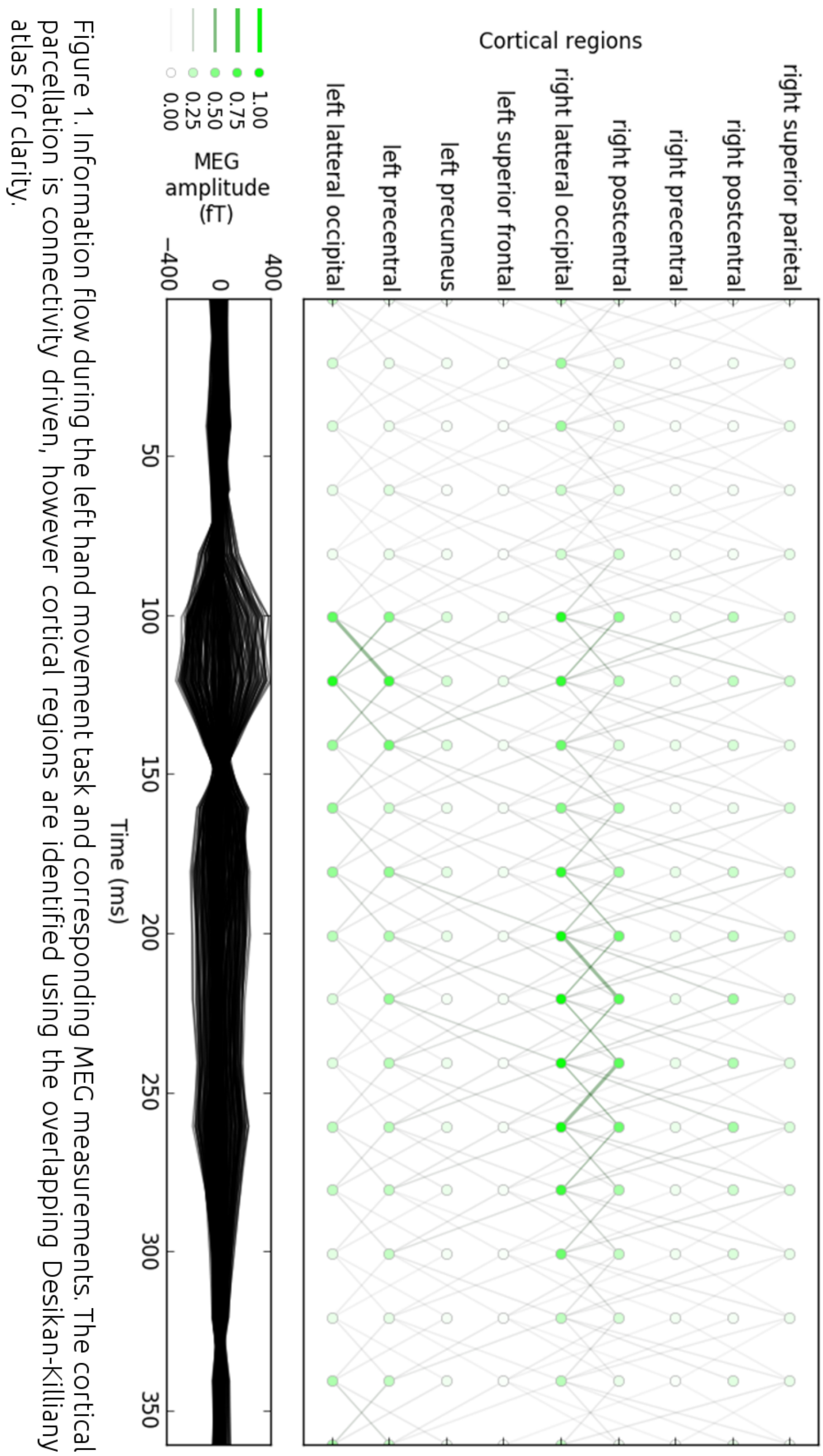

Figure 1: Information flow during the left hand movement task and corresponding MEG measurements. The cortical parcellation is connectivity driven, however cortical regions are identified using the overlapping Desikan-Killiany atlas for clarity.

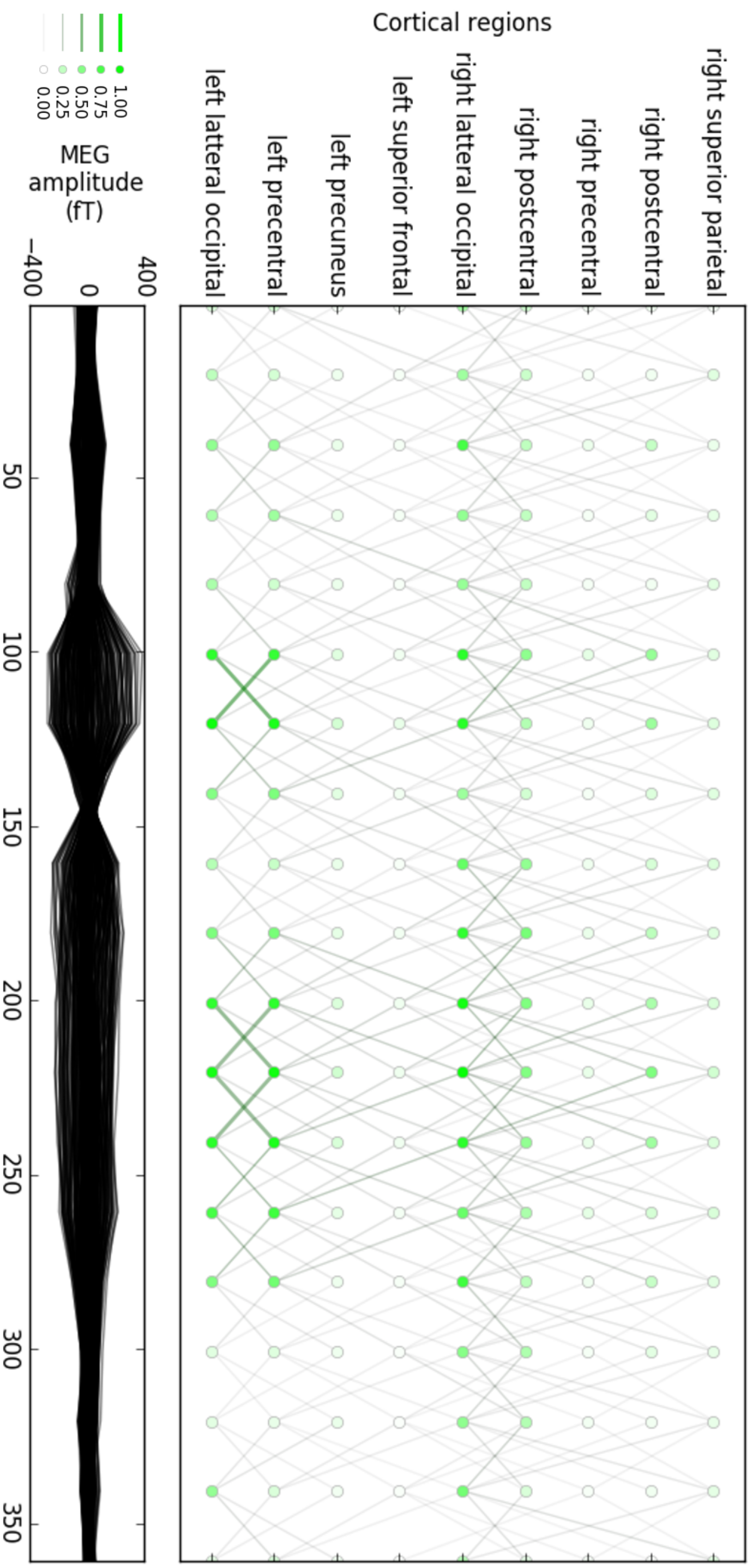

Figure 2: Information flow during the right hand movement task and corresponding MEG measurements. The cortical parcellation is connectivity driven, however cortical regions are identified using the overlapping Desikan-Killiany atlas for clarity.

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